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Energy sources and its Harvesting Techniques for IoT Devices

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ABSTRACT:

For effective functioning of IoT devices, there should be constant and clean source of electric energy to the device. Energy from Power Holding Companies can be interrupted unannounced for one reason or the other. Also, some IoT devices installed in remote areas like thick forest will likely not be powered with energy from Power Holding Companies. Again, Battery is not a perfect option since it has a life-cycle. For constant powering of IoT device, the device needs to harvest its energy from the ambient environment. This will ensure uninterrupted powering and perpetual life-cycle of the devices.

In this paper, energy harvesting is discussed. The main point of discussion is its sources from the ambient environment and the different technologies applied in harvesting them. Though there are many sources of energy and harnessing technologies, the interest of this paper is on energy source and it harnessing technologies for IoT and other mini electronic devices.

Keyword: Energy, source, ambient, harnesssing harvester, IoT, devices

Introduction:

Energy harvesting or energy scavenging is the process of extracting energy from ambient environment to power electronic devices. The harvested energy is used to increase the lifetime and capability of electronics devices by augmenting the battery usage. It is equally used in charging the battery in a situation where secondary battery is used. This technology is also use in energy harvesting systems to power small electronic devices, sensors, and wireless networks (Lloret, Garcial, Catala, & Rodrigues, 2016).

Ambient energy sources include solar radiation, which can be captured using photovoltaic cells or solar panels to convert sunlight into electrical energy. Heat energy from sources like waste heat or temperature gradients can be converted into power using thermoelectric generators. Vibrations and mechanical motion can be harnessed using piezoelectric materials or electromagnetic induction to generate electricity (Adrivan, Conde, Caberos, & Doloriel, 2019).

The advantages of ambient energy harnessing include its potential for sustainability, as it taps into naturally occurring energy sources that are readily available. It also offers the advantage of providing power in remote or hard-to-reach locations where traditional energy sources may be impractical or unavailable. Additionally, ambient energy harvesting can contribute to reducing our carbon footprint and promoting clean energy solutions (Sanislav, Mois, Zeadally, & Folea, 2021).

The importance of energy harnessing for IoT devices:

The importance of energy harnessing for IoT devices cannot be overstated. IoT (Internet of Things) devices are designed to connect and communicate with each other through the internet, enabling advanced functionalities and automation. However, these devices are often small and compact, which means they have limited space for traditional power sources like batteries (Sanislav, Mois, Zeadally, & Folea, 2021).

Energy harvesting techniques play a crucial role in overcoming this limitation by providing a sustainable and efficient power supply for IoT devices. Energy harvesting involves capturing and converting ambient energy from sources such as light, heat, vibration, or RF signals into usable electrical energy. By integrating these energy harvesting technologies into IoT devices, we can ensure their continuous operation without relying solely on conventional power sources (Motlagh, Mohammadrezaei, Hunt, & Zaker, 2020).

There are several key benefits to energy harnessing for IoT devices. First and foremost, it improves their overall efficiency and reliability. With a constant and renewable energy supply, IoT devices can operate autonomously for extended periods, reducing the need for frequent battery replacements or recharging. This is especially significant for remote or inaccessible locations where regular maintenance may be challenging (Lloret, Garcial, Catala, & Rodrigues, 2016).

Moreover, energy harnessing enables IoT devices to operate in environmentally friendly ways. By utilizing renewable energy sources, we can reduce our dependence on non-renewable resources and decrease carbon emissions associated with conventional power generation. This aligns with the principles of sustainability and conservation, making IoT deployment more eco-friendly (Adrivan, Conde, Caberos, & Doloriel, 2019).

Another advantage of energy harvesting is the potential for greater flexibility in device placement and deployment. Since IoT devices can generate their own power, they are not limited to locations with readily available power outlets or batteries. This opens up possibilities for deploying IoT devices in a wider range of environments and applications, including those that were previously impractical or unfeasible due to power constraints (Pozo, Garate, Araujo, & Ferreiro, 2019).

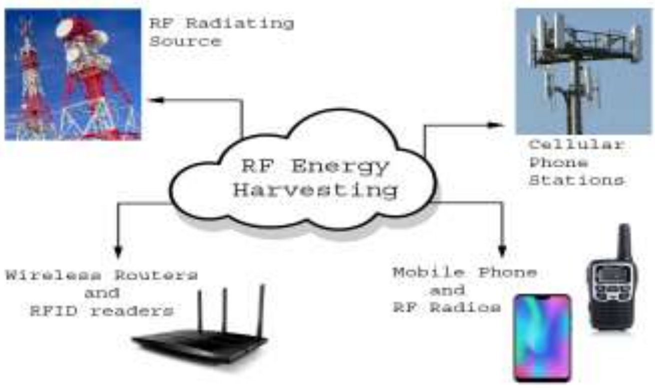
Ambient Energy sources for IoT Devices:

In today's world, where technology is advancing at an unprecedented pace, the Internet of Things (IoT) has become a buzzword. From smart homes to wearable devices, IoT has revolutionized the way we interact with technology. But there's one aspect of IoT that often gets overlooked – energy. How do these devices, which are constantly connected and require power to function, stay powered up? The answer lies in ambient energy sources (Sanislav, Mois, Zeadally, & Folea, 2021).

Ambient energy sources, as the name suggests, are energy sources that exist in the surrounding environment. These sources can be harnessed to power IoT devices, eliminating the need for traditional power sources such as batteries or electrical outlets. This not only makes IoT devices more convenient to use but also reduces their environmental impact. Such energy sources are:

1. RF Energy:

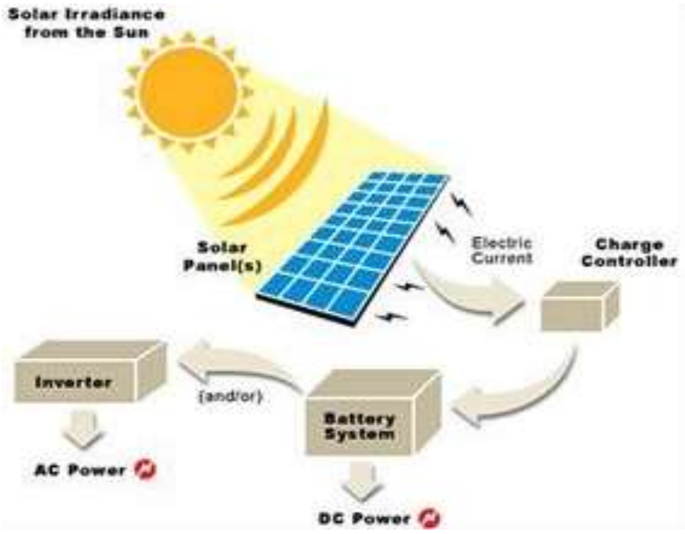
RF (Radio Frequency) energy refers to the electromagnetic radiation with frequencies ranging from 3 kilohertz (kHz) to 300 gigahertz (GHz). It is a form of energy that is used in various applications, including telecommunications, broadcasting, and wireless communication (Pavithra & Arunadevi, 2017). According to (Nechibvute, Chawanda, Taruvinga, & Luhanga, 2017), the several technologies used to harness RF energy are:



- Antennas: Antennas are devices designed to send and receive RF waves. They are crucial for capturing RF energy, converting it into an electrical signal, and vice versa. Antennas come in various shapes and sizes, depending on the intended frequency range and application. For IoT device to harvest RF energy using this technology, an antenna and the device need to be built together.
- Wireless Power Transfer: RF energy can be used for wireless power transfer, allowing devices to receive power without the need for physical connections. This technology is often used in applications like wireless charging, where RF energy is converted into electrical power to charge devices over short distances.
- RFID (Radio Frequency Identification) Technology: RFID utilizes RF energy for identification and tracking purposes. It consists of tags, which contain a unique identifier and respond to RF signals, and readers that emit RF signals to communicate and gather data from the tags. This technology is widely used in supply chain management, asset tracking, and access control systems.
- RF Harvesting: RF energy can also be harnessed by harvesting ambient RF waves present in the environment. This involves capturing and converting the RF energy into usable electrical power. RF harvesting technology is still in its early stages of development but shows promising potential for powering low-power electronic devices.

2. Solar energy:

Solar energy is a renewable source of energy that comes from the sun. It can be harnessed and converted into usable forms of energy. (Hussain, 2021) explained several technologies used to harness solar energy, including:



- Solar photovoltaic (PV) panels: These panels are made up of solar cells that convert sunlight directly into electricity. When sunlight hits the solar cells, it creates an electric current that can be used to power homes, businesses, or other electrical devices.
- Solar thermal systems: These systems capture the heat from the sun to generate thermal energy. They use various techniques like flat-plate collectors, evacuated tube collectors, or parabolic troughs to concentrate and absorb solar energy. The heat can be used for heating water or air, or for generating electricity through steam turbines.
- Concentrated solar power (CSP) plants: CSP plants use mirrors or lenses to concentrate sunlight onto a focal point, where a fluid is heated. The heated fluid then drives a turbine to generate electricity. CSP plants are typically used for large-scale power generation.
- Solar water heating systems: These systems use solar collectors to capture the sun's heat and transfer it to water. This heated water can be used for domestic hot water needs, space heating, or even for industrial processes.
- Solar air conditioning systems: These systems use the sun's heat to power absorption chillers, which provide cooling for buildings. The collected solar energy is used to generate heat for the absorption chiller, replacing the need for traditional electricity.

3. Kinetic energy

Kinetic energy refers to the energy possessed by an object due to its motion. It is a type of energy that can be harnessed and used for various purposes. (Beeby, Torah, & Tudor, 2018) explained several technologies that can be used to harness kinetic energy effectively.

- One common technology used to harness kinetic energy is a turbine. Turbines are devices that convert the kinetic energy of a fluid (such as water or steam) into mechanical energy, which can then be used to generate electricity. For example, hydroelectric power plants use turbines to convert the kinetic energy of flowing water into electrical energy.
- Another technology is regenerative braking, which is commonly used in electric vehicles. When a vehicle brakes, the kinetic energy is converted into electrical energy and stored in the battery for later use. This helps to improve the efficiency and range of electric vehicles.
- Furthermore, piezoelectric materials can also be used to harness kinetic energy. These materials generate electrical energy when subjected to mechanical stress or vibration. They can be integrated into various devices, such as roads or flooring, to capture the kinetic energy produced by vehicles or footsteps.
- In addition, kinetic energy can also be harnessed through technologies like flywheel energy storage systems and ocean wave energy converters. Flywheels store kinetic energy in a spinning rotor, which can be released on demand to generate electricity. Ocean wave energy converters use the kinetic energy of ocean waves to generate electrical power.

4. Light energy:

Light energy is a form of energy that we experience through visible light and other electromagnetic waves. It plays a crucial role in various aspects of our lives, including technology. Harnessing light energy involves utilizing it for various purposes, such as generating electricity, communication, and illumination. According to (Jabbar & Jeong, 2022) the following are methods of harnessing light energy:

- One of the most common technologies for harnessing light energy is solar power. Solar panels are designed to capture sunlight and convert it into electricity. This process, called photovoltaic conversion, involves the use of semiconductors that absorb light and release electrons, creating an electric current.

- Another technology is optical fiber communication, which utilizes light signals to transmit information through thin strands of glass or plastic fibers. Light pulses carry data over long distances at high speeds, making it an efficient and widely used form of communication.
- Light energy is also harnessed for illumination purposes. Light-emitting diodes (LEDs) are highly energy-efficient devices that produce light when an electric current is passed through them. They are used in various applications, from lighting up homes and offices to display panels and electronic devices.

5. Bio energy:

Bio energy refers to the energy derived from organic matter, such as plants or animal waste, through various processes like combustion or fermentation. It is a renewable energy source that can be harnessed to power IoT (Internet of Things) devices. (Proskurina, Stolarski, & Vakkilainen, 2023) explains some of the technologies for harvesting Bio energy.

- There are several technologies used to harness bio energy for IoT devices. One common method is through the use of biofuel cells, which convert chemical energy from organic matter into electrical energy. These fuel cells can be integrated into IoT devices to provide a sustainable power source.
- Another technology is anaerobic digestion, where organic matter is broken down by microorganisms in the absence of oxygen. This process generates biogas, which can be used as a fuel to power IoT devices. Biogas can be produced from various feedstocks, such as agricultural waste, food waste, or sewage.
- Additionally, bio energy can also be obtained through the direct conversion of biomass into electricity or heat. Biomass, which includes plants, wood, or agricultural residues, can be burned or used in thermal conversion processes like gasification to produce energy for IoT devices.

Energy management in IoT devices:

Energy management in IoT devices is a crucial aspect to consider in order to optimize their performance and overall efficiency. There are several techniques and strategies that can be employed to effectively manage energy consumption in IoT devices:

1. Power-efficient hardware: Selecting energy-efficient components and hardware for IoT devices can greatly contribute to minimizing power consumption. This includes using low-power microcontrollers, sensors, and efficient power supplies.

2. Sleep modes and wake-on-demand: Implementing sleep modes in IoT devices allows them to conserve energy when not actively performing tasks. Wake-on-demand features enable the device to wake up only when necessary, reducing unnecessary power usage.

3. Data compression and processing: Employing data compression techniques and processing data locally on the device instead of transmitting raw data to the cloud can significantly reduce energy consumption. This eliminates the need for constant communication and data transfer.

4. Adaptive transmission techniques: Adjusting the transmission power and rate based on signal strength and distance can help minimize energy consumption in wireless communication. Using low-power wireless protocols such as Bluetooth Low Energy (BLE) or Zigbee can also be beneficial.

5. Energy harvesting: Incorporating energy harvesting mechanisms, such as solar panels or kinetic energy harvesters, can help supplement or recharge the device's power source. This ensures prolonged operation without solely relying on battery power.

6. Intelligent scheduling and task prioritization: Utilizing intelligent scheduling algorithms that prioritize critical tasks and minimize idle time can optimize energy consumption in IoT devices. This can be done by grouping and batching data transmissions or processing tasks for efficient energy management.

By employing these energy management techniques, IoT devices can operate more efficiently, enhance battery life, and reduce overall environmental impact.

Conclusion:

The energy sources from the ambient environment are discussed. Such sources are sun, light, RF, kinetic, Biological energy source. When harvested through a given technology, the energy from these source are too small and are unable to power IoT device, therefore energy management/amplifier circuit are added to the system. It is worthy to note that the common source of energy for powering IoT device is the solar, RF, Kinetic and Light energy. The technologies for harvesting energy from these sources are as discussed in this paper.

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